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A TABULATION OF THE 32 CRYSTAL CLASSES[1]

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The 32 crystal classes, each characterized by its unique combination of symmetry elements, are now firmly established. Representatives of all but one of them (the trigonal dipyramidal class) have been found, either among minerals or laboratory products. The prediction of Hessel,[2] professor of mineralogy at the University of Marburg, of the thirty-two crystal classes in 1830, when only seventeen of them were known, must rank as one of the notable achievements of science in the nineteenth century.

Since there are not many textbooks that include a complete list of the 32 crystal classes, the writer presents the accompanying tabulation. While it must be recognized that in an elementary course in mineralogy not more than ten or eleven crystal classes (classes 2, 5, 8, 15, 18, 19, 20, 27, 30, 31, and 32 are the most important) can be studied in any detail, there are convincing arguments in favor of presenting a complete list of the classes for the consideration of the student. In some respects the table of crystal classes bears the same relation to geometrical crystallography that the periodic table of elements does to inorganic chemistry.

In the tabulation here presented there are seven vertical columns which give in order: (1) the crystal system, (2) the number of the class, (3) the name of the class, (4) the number of faces in the general form of the class, (5) symbols for the symmetry of the class, (6) a prominent example of the class, and (7) the symbols used by Schoenflies.

1. CRYSTAL SYSTEMS

Six systems are recognized instead of seven, the hexagonal being divided into two subsystems, the rhombohedral and the hexagonal. This is the plan adopted by Fedorov, who, however uses syngony and hyposyngony instead of system and subsystem.

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[1] Paper presented at the seventh annual meeting of the Mineralogical Society of America, Madison, Dec. 28, 1926.

[2] *Krystallometrie, oder Krystallonomie und Krystallographie*, **1830**, (reprinted in *Ostwald's Klassiker der Exakten Wissenschaften*, Nos. 88 and 89, *Leipzig*, **1897**).

One important point that should be emphasized here is that the trigonal dipyramidal (no. 21) class and the ditrigonal dipyramidal (no. 22) class belong to the hexagonal subsystem, or to the hexagonal system proper if one prefers seven systems, and not to the trigonal or rhombohedral subsystem (or system). In six books published within the last decade, the two classes mentioned have been assigned to the trigonal system or to the trigonal division of the hexagonal system. Evans and Davies,[3] who correctly assign these two classes to the hexagonal system proper, state that Hilton in 1907 was the first to point out that this is their proper place but they are in error here, for Bravais[4] as early as 1849 placed these two classes in the hexagonal (sénaire) system proper and not in the trigonal or rhombohedral (ternaire) system.

That the trigonal dipyramidal and ditrigonal dipyramidal classes belong to the hexagonal subsystem or hexagonal system proper and not to the trigonal or rhombohedral subsystem or system is definitely proved by the application of the theory of groups.[5] The trigonal dipyramidal (no. 21) and ditrigonal dipyramidal (no. 22) classes are subgroups of the dihexagonal dipyramidal (no. 27) class, but not of the hexagonal or ditrigonal scalenohedral (no. 20) class.

A still better argument for placing these two classes in the hexagonal subsystem or hexagonal system proper is found in the fact that these classes (nos. 21 and 22) together with classes nos. 23 to 27 inclusive have as their space lattice a hexagonal prism only, while classes 16 to 20 inclusive have either a rhombohedron or hexagonal prism as a space lattice.[6] We know from X-ray work of the last decade or so that the space lattices of crystals are fundamental.

There is general agreement on the assignment of the other classes to the systems indicated.

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[3] Elementary Crystallography, p. 130, *London*, (1924).

[4] *Jour. de l'Ecole Polytechnique.* Vol. 34. Reprinted in *Etudes Cristallographiques*, III ^{me} partie, pp. 273–274, *Paris* (1866).

[5] See paper by the writer, *Proc. Am. Acad. Arts and Sci.*, vol. 61, p. 199 (1926).

[6] Hilton, *Mathematical Crystallography*, pp. 239–240, *Oxford* (1903).

2. NUMBERS OF THE CLASSES

The classes are numbered, the class without any symmetry being no. 1 and the class with the highest grade of symmetry being no. 32. This seems to be a better arrangement than the one that places the hexoctahedral class first and the asymmetric class last. It does not mean that the student necessarily begins his crystallography course with the triclinic system. The writer in presenting the subject of elementary crystallography always starts with the orthorhombic system. There are at least two textbooks[7] in which the orthorhombic system is treated first.

The order of the classes in the tabulation is the same as Groth's arrangement,[8] except that the trigonal dipyramidal class is placed immediately after the hexagonal scalenohedral class. Groth's numbers 19, 20 and 21 then become, respectively, my numbers 21, 19 and 20. When this change is made, the order of the classes is only in minor part arbitrary. Each of the 32 classes constitutes a mathematical "group"[8a] with its "subgroups" and as has been shown recently by the writer,[9] with the present arrangement of the classes the subgroup of each group appears before the group itself. This is not true of Groth's arrangement.

Even if classes 16 to 20 inclusive are treated as a separate rhombohedral or trigonal system they should not be separated from classes 21 to 27 inclusive.

The present arrangement of the classes first appeared in a textbook by the writer.[10]

3. NAMES OF THE CLASSES

The name of the class given in the third column is an adjective derived from the name of the general form except that in the case of the class without any symmetry the term asymmetric is preferred to pediad,[11] a name derived from the one-faced form, pedion. This method, which was first used by Groth,[12] is in my opinion the best way of designating the various crystal classes. Groth's names for the isometric classes may be simplified in accordance with the suggestions of Moses.[13] It should be noted that the term dipyramidal is used instead of bipyramidal. Wulff was the first to make this change, but he has been followed by Groth and others[14] in recent years.

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[7] Rogers, *Introduction to the Study of Minerals*, 1st ed. *New York*, **1912**, Evans and Davies, *loc. cit.* (1924).

[8] *Physikalische Krystallographie*, 4th ed., pp. 335-337, *Leipzig* **(1905)**.

[8a] See footnote 15, p. 575.

[9] *Proc. Am. Acad. Arts and Sci.*, vol. **61**, p. 200 (1926).

[10] *Introduction to the Study of Minerals and Rocks*, 2nd ed., p. 80, *New York*, **1921**.

[11] The term used by Lewis, *A Treatise on Crystallography*, p. 148, *Cambridge* **(1899)**, who introduced it. Most authors use "pedial" instead of "pediad."

It has been objected that some of these names for the classes are cumbersome. It is true that more than half of them are rather long, but the point may be emphasized that the student must become familiar with the names of the general forms in any event. If the same names are used for the crystal classes then he is not required to learn a new set of names, which is a distinct advantage.

Names referring to the varying types of merohedrism (hemihedrism, hemimorphism, tetartohedrism, and ogdohedrism) are also widely used. The use of terms involving merohedrism imply that crystal systems are fundamental whereas we know now that crystal classes and not crystal systems are fundamental. In view of this fact, ideas based upon merohedrism are at present of historical interest only.

In referring to a particular system it is convenient to use a general term for the class with the maximum symmetry in that system. For this purpose many authors use "holohedral," but "holosymmetric" is preferable for the reason given in the preceding paragraph.

Other sets of names for the various crystal classes have been proposed by Dana, Lewis, Miers, Spencer, Evans, Wherry, and others.

While there may be slight advantages in some of the class names proposed by these authors, the writer has come to the conclusion that names of crystal classes based upon names of general forms furnish the most consistent logical scheme of nomenclature that has yet been devised. Groth's names are more widely used than any other set of names; they are logical, based upon a uniform plan, are free from ambiguity, and are international in character.

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[12] *loc. cit.*

[13] *Characters of Crystals*, pp. 57–58, *New York*, (1899).

[14] See Boldirev, *Zeit. f. Kryst. u. Min.*, vol. 62, pp. 145–150 (1925).

4. Number of Faces in the General Form

The numbers, 1, 2, 3, 4, 8, 12, 16, 24, and 48, of the fourth column are the number of faces in the general form of each class. Each class constitutes a group.[15] There are as many operations in the group as there are faces in the general form and the number of operations defines "the order of the group." These numbers have been called "symmetry numbers" by Shearer.

5. Symbols for Symmetry Elements

In the fifth column of the table symbols for the symmetry elements are given. The combined symbols for any class are sometimes known as the "symmetry formula."

A_n stands for an n-fold axis of symmetry, P, for a plane of symmetry, and C, for a center of symmetry. The symbols P and C were used by Bravais, and A_n was first used, as far as can be ascertained, by Voigt.[16] A number before a symmetry element refers to the number of axes or planes of symmetry present. The compound symbol, $\overline{AP}_n$ used for an axis-plane of rotatory-reflection was devised by the writer.[17] The compound symbol, $\overline{CA}_n$, also devised by the writer,[18] is used for an axis-center of rotatory-inversion.

In a recent mathematical study of crystal symmetry the writer[19] in order to account for all the faces of the general forms of crystals found it necessary to employ both rotatory-reflections and rotatory-inversions in addition to ordinary rotations, reflections, and inversion.

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[15] "Group" is a mathematical term used for a series of operations which have the following properties: (1) "The product (the result of one operation followed by another) of any two of them is equivalent to another operation of the series." (2) "The inverse of any operation is also a member of the series." The symmetry operations of a crystal (rotation, reflection, inversion, rotatory-reflection, and rotatory-inversion) form a group since the above conditions are fulfilled.

[16] *Die Fundamentalen Physikalischen Eigenschaften der Krystalle*, pp. 191–193, *Leipzig* (1898).

[17] *Introduction to the Study of Minerals*, p. 7, *N. Y.* (1912). The logotype symbol AP, but with the right limb of the letter A coincident with the vertical line of P, is now widely used as an abbreviation for "Associated Press," but the writer claims priority!

In this article it is necessary to substitute the symbol $\overline{\text{AP}}$ for the logotype symbol.

[18] *Proc. Am. Acad. Arts and Sci.*, vol. **61**, p. 171 (1926).

[19] *Proc. Am. Acad. Arts and Sci.*, vol. **61**, pp. 161–203(1926).

Symmetry elements include or imply "powers" of operations, that is, some operations may be obtained by repeating another operation a certain number of times. For example, $a_{180°}$ is the second "power" of $a_{90°}$ and $a_{270°}$ the third "power." The following tabulation shows the relation between symmetry elements and symmetry operations. Here and elsewhere in this article lower case letters refer to operations and upper case letters to elements. 1 is the symbol for identity or the identical operation.[20]

Symmetry Elements Symmetry Operations

$A_2 = 1,\ a_{180°}$

$A_3 = 1,\ a_{120°},\ a_{240°}$

$A_4 = 1,\ a_{90°},\ a_{180°},\ a_{270°}$

$A_6 = 1,\ a_{60°},\ a_{120°},\ a_{180°},\ a_{240°},\ a_{300°}$

$P = 1,\ p$

$C = 1,\ c$

$\overline{AP_4} = 1,\ \overline{ap}_{90°},\ a_{180°},\ \overline{ap}_{270°} = \overline{\mathrm{CA}_4}$

$\overline{AP_6} = 1,\ \overline{ap}_{60°},\ a_{120°},\ c,\ a_{240°},\ \overline{ap}_{300°}$

$\overline{CA_6} = 1,\ \overline{ca}_{60°},\ a_{120°},\ p,\ a_{240°},\ \overline{ca}_{300°}$

When $n/2$ is even, rotatory-reflections and rotatory-inversions are equivalent; in this case rotatory-reflections are to be preferred. With these operations and only with these may all the faces of the general forms of the 32 classes be accounted for.

There remains to be explained that some of the symbols in the symmetry column are enclosed in parentheses and some in brackets. Parentheses indicate that an inversion or a reflection is one of the powers, respectively, of a rotatory-reflection or rotatory-inversion. Brackets indicate that the symmetry element so designated has one or more operations in common with the symmetry element that precedes it. For example, in classes 25 and 27 $a_{120°}$ and $a_{240°}$ are common to A_6, $\overline{AP}_6$, and $\overline{CA}_6$, and so the two latter symbols are enclosed in brackets.

It is recognized that axes or planes of symmetry designated by nA or nP are not always equivalent, but to indicate non-equivalent axes or planes by different exponents would often make the symmetry symbols too complicated. Class 15, for example would become $A'_4\ [\overline{AP'}_4] \cdot 2A''_2 \cdot 2A'''_2 \cdot P' \cdot 2P'' \cdot 2P''' \cdot C$.

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[20] This is a device for mathematical completeness. For an n-fold axis of symmetry, there are n operations, provided the identical operation is used.

6. Examples

The sixth column of the table gives an example of each of the crystal classes except class 21, for which no example has yet been found. Examples of minerals are given by name and examples of prepared compounds of the laboratory are indicated by the chemical formula.

7. Symbols of Schoenflies

The last column gives the symbols used by Schoenflies.[21] These point group symbols are used for the most part as a basis for designating space groups. For example D_{3d}^2 is one of the space groups of the point group $D_3{}^d$. Some of the objections to the symbols of Schoenflies have been pointed out by Wyckoff.[22] Wyckoff emphasizes the desirability of adopting a more simple and logical notation of symbols for point groups and space groups and suggests a set of symbols which is a modification of a set put forward by Hilton. I agree with Wyckoff that we need a simple, convenient, and logical notation of point group symbols (more condensed than symmetry symbols), but in view of the necessary use of both rotatory-reflections and rotatory-inversions as symmetry elements, it is not advisable to use such expressions, for example, as 3Ci and 3Di as point group symbols for the rhombohedral and hexagonal scalenohedral classes, respectively. The same objection may be raised to the symbols of Hilton[23] and Evans.[24]

Use of Group Theory in Geometrical Crystallography

In conclusion I wish to call attention to the advantage of using the mathematical theory of groups in the advanced study of geometrical crystallography.

An analytical study of crystal symmetry with the aid of the theory of groups establishes definitely just what constitutes the symmetry operations and symmetry elements of crystals.[25]

The use of operations introduces into crystallography a dynamic conception of geometry which becomes most fascinating.

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[21] *Theorie der Krystallstruktur*, Leipzig, (**1923**).

[22] *Am. Jour. Sci.*, [5], vol. **6**, pp. 288–290 (**1923**).

[23] *Mineralog. Mag.*, vol. **14**, p. 261 (1907); *ibid.*, vol. **19**, p. 319 (1922).

[24] *Nature*, vol. **113**, pp. 80–81, (1924).

[25] See paper by the writer, *The Mathematical Study of Crystal Symmetry*, *Proc. Am. Acad. Arts and Sci.*, vol. **61**, pp. 161–201 (1926).

SPODUMENE AND AUTUNITE FROM ALSTEAD, NEW HAMPSHIRE

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During an investigation in August and September, 1927, of the pegmatites of the Gilsum area, Cheshire County, New Hampshire, two minerals, spodumene and autunite, were found which are not known to have been reported before from this district. It seems worthwhile, therefore, to put this occurrence on record.

The pegmatites of this region are intruded into a mica schist with which they have rather sharp contacts, although there is some lit-par-lit injection on a small scale as well as tourmalinization of the wall rock. The essential minerals, aside from quartz, are feldspar and muscovite, both of which are extensively quarried in the area. The accessory minerals include biotite, black tourmaline, beryl, garnet, apatite, spodumene, autunite, and zircon. The spodumene and autunite came from the quarry of the New Hampshire Mica and Mining Company in the town of Alstead, about one and four-fifths miles north northwest of Gilsum village.

The spodumene crystals occur on an inaccessible wall near the top of the west face of the quarry. They were much concealed by material washed down from the surface, but the crystals exposed appeared to be of the order of several feet in length. From blocks which had fallen from the wall a few crystals were obtained, the largest of which was six inches long, four inches wide, and one and one-half inches thick, but it did not represent the entire crystal. The spodumene occurs associated with tourmaline, garnet, apatite, feldspar, quartz, and sericite. The material shows a fairly good crystal form although it is much altered by weathering to a soft powdery substance of a light pink color, probably cymatolite, a mixture of albite and muscovite. The crystals show the characteristic spodumene etching and are colorless to white, pink, or light green. One specimen showed both a pink and a green color in the same crystal. The pink spodumene suggests kunzite, which in New England has been reported from Branchville, Connecticut.[1] Green spodumene or hiddenite is found in North Carolina.[2] Spodumene is also reported from a number of localities in New England,[3] and in New Hampshire occurs at Winchester in white, well-formed crystals.[4]

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[1] Brush, G. J., and Dana, E. S., On the mineral locality at Branchville, Connecticut. Spodumene and the results of its alterations, *Am. Jour. Sci.*, 3rd ser., **20**, 257–285 (1880).

At the same quarry autunite, the hydrous phosphate of uranium and calcium, is found in small micaceous flakes or scales of a light greenish-yellow color lying between plates of albite of the variety cleavelandite. A similar occurrence in the pegmatites of Maine was reported by Bastin.[5] The mineral also occurs at the same quarry in the tourmalinized portion of the wall rock. The largest of the autunite flakes was 4 mm. in diameter, but most of the scales are considerably smaller. They are characterized by their well-developed cleavage and brittleness as well as yellow color. Under the microscope the mineral is seen to have a biaxial negative character with a very small optical angle. Autunite is reported from several localities in New England,[6] and in New Hampshire occurs at Acworth[7] in small tabular crystals of a light green and straw-yellow color coating the feldspar.

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[2] Kunz, G. F., History of the gems found in North Carolina, *North Car. Geol. Surv., Bull.* 12, p. 45–48 (1907).

[3] Dana, E. S., The system of mineralogy of James Dwight Dana. Descriptive mineralogy, 6th ed., p. 368, *New York* (1892).

[4] Hitchcock, C. H., The Geology of New Hampshire, Vol. **III**, Part IV, pp. 60, 136, *Concord* (1878).

[5] Bastin, E. S., Geology of the pegmatites and associated rocks of Maine, *U. S. Geol. Survey Bull.* 445, pp. 16, 78 (1911).

[6] Dana, E. S., *op. cit.*, p. 858.
Bastin, E. S., *op. cit.*, pp. 16, 53, 78, 88, 102, 104.

[7] Hitchcock, C. H., *op. cit.*, p. 126.

THE CRYSTAL FORM OF BOLEITE*

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Boleite, the composition of which is essentially $PbCl_2 \cdot CuO_2H_2$, with a considerable content of AgCl, is a mineral whose crystallographic character is not well understood. According to the external appearance of the crystals, they belong to the cubic system, commonly occurring as the form (100), or as a combination of (100) and (111). However, according to the investigation of G. Friedel,[1] they should be interpreted as intergrowths of tetragonal crystals. But their cubic habit is not in harmony with the axial ratio $a:c = 1:3.996$; such a large value for the c axis usually being found only in crystals with a pronounced foliated development.

Accordingly this study of the crystal form of boleite was undertaken. Dr. F. Mussgnug, at my suggestion, has determined the lattice constants by means of X-ray methods. Films of very good quality gave the following results:

Direction	Distance in Ångstrom Units		
	Observed		Calculated
[100] Cube edge	15.78 15.63 15.69 15.41 15.45	average 15.6	—
[110] Face diagonal	22.12 22.00 21.84 21.80 21.85	average 21.9	$22.06 = a\sqrt{2}$
[111] Body diagonal	26.78 26.72 26.85 26.85 26.80	average 26.8	$27.0 = a\sqrt{3}$

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* Manuscript submitted in German and translated by Dr. L. S. Ramsdell, Mineralogical Laboratory, University of Michigan.

[1] *Bull. Soc. Min. Paris*, 1906, **29**, 55.

The values for [100] and [110] were obtained by the oscillation method from a natural (100) face, and that for [111] from an artificial (110) face. The following results were obtained from three films:

Reflection	Intensity	δ Calculated	δ Observed	Remarks
002	—	5° 40′	5° 40′	Two films from (100) face with [100] and [110], resp., as axes of rotation.
003	m. st.	8° 30′	8° 30′	
004	v. st.	11° 22′	11° 24′	
005	st.	14° 16′	14° 24′	
006	st.	17° 11′	17° 24′	
222	v. st.	9° 50′	9° 50′	One film from (111) face, with [101] as rotation axis.
333	st.	14° 50′	14° 54′	
444	m. st.	19° 57′	20° 3′	
555	m.	25° 15′	25° 30′	

For the calculations, the wave length value was 1.54Å. This value, together with the distance 15.6Å for the cube edge, gave the quadratic formula, $\sin^2\delta = 0.00244(h^2+k^2+l^2)$.

From a comparison of the observed and calculated values, it is evident that the axial ratio cannot be $a:c=1:3.996$. To be exact, this evidence merely proves that the outer layer of the crystal is cubic. This outer layer must have a considerable thickness, for the values for [111] were determined on a cut face, but nevertheless gave a value of $a\sqrt{3}$. The isotropic nucleus can be seen under the microscope, as is mentioned by Friedel, so it is reasonable to conclude that this portion of the crystal is likewise cubic.

This cubic structure has a unit cube with $a=15.6$Å. The compound $PbCl_2 \cdot CuO_2H_2$ has the molecular weight $M=375.8$. The density of boleite is given as 5.054. This would mean that there are 31.2 molecules in the unit cell, if the content of AgCl is ignored. There would be a reduction in the molecular weight, if we assume that there is some isomorphous substitution of AgCl. There would then be satisfactory agreement with the assumption that there are 32 molecules in the unit cell.

Furthermore, there are cube-like crystals, whose outer form can be regarded as right angled interpenetrations of two simple cubes. The outer layer of these crystals are pseudoboleite, according to

G. Friedel. We have determined the spacing for such crystals, including the outer layer, and find that for [100] there is complete agreement with the value $a=15.6$Å. This outer layer is then indentical with that of the regular boleite. Accordingly, there is doubt as to any difference between the two minerals, and further research should show whether pseudoboleite, with its axial ratio of $a:c=1:2.023$, really exists.

Under the microscope the structure of the crystals appears rather complex, with both isotropic and anisotropic areas. Such a structure is not revealed at all by the X-ray data. The diagrams show throughout a regular arrangement and, in fact, for the axes of rotation, [100] and [110] they are symmetrical with respect to the zero line. Furthermore, we have obtained a very good Laue diagram from a (100) cleavage, which shows a four-fold axis of symmetry, as well as 2+2 planes of reflection. The films show no evidence not in harmony with the cubic arrangements, possessed by any of the symmetry classes T_d, O, or O_h. From the X-ray data, there is scarcely any other arrangement besides regular cubic possible.

The anisotropic character of portions of the crystals, as revealed by the polarizing microscope, can be considered as due to optical anomalies. The atomic centers of gravity are arranged in a cubic lattice. But the atoms themselves are in a strained condition, perhaps because of the isomorphous replacement, and this strain is the cause of the anomalous optical behavior.

The group boleite-pseudoboleite-cumengite still shows unsolved problems with respect to its chemical and crystallographic properties. There appears to be a possibility of solving these problems by the X-ray method. We plan to extend the chemical and crystallographic study as much as possible and have already begun the investigation of this rather comprehensive problem which embraces a large mass of details.

THE RUTHERFORD MINES, AMELIA COUNTY, VIRGINIA

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The vicinity of Amelia Court House, Virginia, has long been known as one that abounds in pegmatite dikes containing rare and unusual minerals. Since the first extensive account of the locality by Fontaine[1] in 1883 nearly forty papers have been published on various phases of the mineralogy of this region. The papers were either of a very general nature or restricted to the description of a particular mineral or group of minerals found. The purpose of the present paper is to review the geology and mineralogy of the deposits that have yielded so many minerals and to report certain new information, a recent survey having shown that the rare minerals for the most part are confined to two dikes at the Rutherford Mines and are not found in the greater number of dikes nearby. From the two dikes at the Rutherford Mines thirty-three species of minerals have been reported, while from the other dikes of the area only half a dozen or so varieties are known. The famous Amelia Court House mineral locality is really restricted to the dikes at the Rutherford Mines.

The locality is in the Virginia Piedmont a moderately dissected plateau without any marked elevations. The rocks enclosing the pegmatites are of pre-Cambrian age, the prevailing type being a biotite gneiss. Diorite and diabase dikes occur to a limited extent. The gneiss has a porphyritic to "augen" texture and a well developed gneissosity which has a general northeast strike that averages N 33°E.

An approximate mineral composition as determined by micrometer measurements is: feldspar 60 per cent, quartz 24, biotite 11, muscovite 3, garnet 1 and accessory minerals 1 per cent. A chemical analysis shows the gneiss to be between a sodipotassic *dacase* with the subrang name *adamellose* and a sodipotassic *monzonase* with the subrung name *monzonose.*

The Rutherford Mines are located one and one-fourth miles north of Amelia and one mile southwest of the main producing area in this district. The mines consist of two openings about

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[1] Fontaine, W. H. Notes on the Occurrence of Certain Minerals in Amelia County, Virginia. *Am. Jour. Sci.*, 25, pp. 330–339 (1883).

300 feet apart along a north-south line and are located on two parallel dikes that average 30 feet wide and are traceable along the strike for nearly one-fourth mile. The strike is east-west and the dip nearly vertical. The mines have not been operated in the last 40 or 50 years and the openings at the present time are nearly filled. In one of the openings there is a pond of water 150 feet long and 50 feet wide. It is reported that the deepest workings extended to a depth of 150 feet. Many mineral species can still be obtained from the dumps.

The prevailing texture of the pegmatites in these deposits is different from that of the other pegmatites in this area. The texture is determined largely by the principal mineral, albite, which occurs as beautifully crystallized, platy, reticulated, fragile masses. The rare and unusual minerals occur in the interstitial spaces. In addition to this texture there are occasional graphic intergrowths. Miarolitic cavities usually lined with quartz crystals are sometimes developed. A fourth kind of texture results from parallel growths of green microcline and muscovite. Occasional inclusions of the enclosing rock, biotite gneiss, occur along the contact. The dominant texture developed in the other dikes in this vicinity is pegmatitic, with occasional graphic and perthitic intergrowths. The nearest approach to the reticulated texture prevalent in the two dikes at the Rutherford Mines is a cellular texture developed in some of the dikes on the Jefferson property, about two miles northeast of these mines. Here the cell walls are of albite and are lined inside with small crystals of muscovite.

The minerals reported from the pegmatite dikes at the Rutherford Mines are given below. Those starred can be collected at the present time.

*Albite, three varieties
*Microcline, two varieties
*Muscovite
*Lepidolite
*Biotite
*Quartz, three varieties
*Garnet, three varieties
*Orthoclase
*Oligoclase
Fluorite
Apatite
Columbite
Allanite
Fergusonite
Topaz
*Tourmaline
*Beryl
Zircon
Ilmenite
Galena
Stibnite
Pyrite
Cerussite
Anglesite
*Calcite
*Hatchettolite

*Microlite
*Manganotantalite
Monazite
Helvite
*Cyrtolite
*Leverrierite
Pyrochlore

MINERALOGICAL NOTES

Albite, the most abundant mineral, exhibits three varietal forms. The first form is a beautifully crystallized, reticulated, snow white, nearly transparent variety. It occurs in cleavable masses of considerable size and contains other minerals, as microlite, in the interstices. The second form is a pea green platy albite known as cleavelandite and is of a high degree of purity. This variety is not found elsewhere in this area, nor has it been reported from any other dikes in the state. In the interstices of this mineral there is often an amber colored calcite, which has taken its form from that of the cavity it filled, indicating that it has been formed subsequently to the albite. The third form is a pure white albite with a blue sheen. Under the microscope numerous gaseous inclusions were observed, which may account for the color effect. Good specimens of all three varieties can be obtained at the present time. The indices of albite are as follows: $\alpha = 1.528$; $\beta = 1.532$; $\gamma = 1.539$.

Microcline has two varietal forms. The first is pink to cream colored and occurs as graphic intergrowths with quartz. The second form is amazonstone, with a range in color from pea green to deep blue green. This variation may be gradational or sharply divided. Professor Papish of Cornell University kindly consented to make a spectroscopic analysis of this unusual variety. He found in addition to those elements appearing in the chemical analyses of this mineral, sodium in amounts over two per cent, a trace of lithium and a very small trace of barium, caesium and thallium. This variety occurs intergrown with quartz and with plagioclase feldspar and as parallel growths with muscovite, the individual bands being less than a centimeter thick. The cleavage lines of the muscovite can be discerned on the surface of the microcline.

Orthoclase is the least abundant of the feldspars and forms intergrowths with the other feldspars and with quartz.

Quartz is present in three varietal forms. Two of the varieties, amethyst and cairngorm, are no longer present in the dumps. Amethyst of the gem variety was reported by Page.[2] Several beautiful specimens of cairngorm are in the possession of Mr. Pinchbeck, a farmer who lives in this locality. It was also reported by Fontaine.[3] The third variety is a transparent to semi-transparent quartz with a greasy to watery appearance. It occurs intergrown with feldspar.

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[2] Page, C. C., The Virginias, Vol. 6, pp. 24–25 (1885).

Muscovite has two varietal forms. The first form is an amber colored muscovite, which in thin sheets has a light brown color. This variety has furnished the commerical grade. It is reported that about 200,000 pounds were taken from these mines. Some of the largest sheets measured 22 by 24 inches. This variety occurs as books, pockets and flakes distributed through the feldspar. The second form is light green and occurs as flakes and small books associated with albite chiefly cleavelandite. There is associated with this variety the pink lithium mica, lepidolite. Biotite is present in small amounts near the contact and is probably derived from the biotite gneiss.

Garnet occurs in three varietal forms. The first form is a red almandite occurring near the contact, both in the wall rock and in the pegmatite. The second form is a reddish-brown spessartite. Some of the largest ones measured three inches in diameter. A gem cut from this mineral has been pictured by G. F. Kunz.[4] A third variety, topazolite, has been reported by Dana.[5] Only the first variety, almandite, can be found in the dumps at the present time.

Apatite has been reported from the Rutherford Mines, though none has been found in recent years. It occurred as translucent, white crystals with a shade of violet and with a vitreous luster. The mineral was quite fragile. When heated the mineral phosphoresced with a yellow light. The formula as computed from the analysis made by G. H. Rowan[6] was $Ca_3P_2O_4 \cdot 1/3CaF_2$.

Fluorite and its phosphorescent variety, chlorophane, were reported and described by G. F. Kunz.[7]

The rare minerals, microlite, columbite, allanite, monazite, fergusonite were reported and described by W. H. Fontaine.[8]

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[3] Fontaine, W. H., *op. cit.*

[4] Kunz, G. F., Gems and Precious Stones of North America, p. 180.

[5] Dana, J. D., System of Mineralogy, 6th Ed., p. 1071 (1892).

[6] Rowan, G. H., *Chem. News*, Vol. **50**, p. 208 (1884).

[7] Kunz, G. F., Chlorophane of Amelia Co., Va., *Amer. Jour. Sci.*, Vol. **26**, p. 235 (1884).

[8] Fontaine, W. H., *op. cit.*

Chemical analyses of microlite, columbite and allanite were made by F. P. Dunnington and reported in the *Amer. Jour. Sci.* and the *Amer. Chem. Jour.* during the years 1881 and 1882. Helvite was first identified by H. C. Lewis. It was analyzed by R. Haines[9] and Sloan.[10] Manganotantalite was first identified from this locality by O. I. Lee and E. T. Wherry.[11] Of these rare minerals the writer was able to find only microlite and manganotantalite. The microlite was found as small octahedral crystals occurring in the interstices of the reticulated, platy, pale green albite. The manganotantalite was found with a similar mode of occurrence and was present as blade-like fragments of a reddish brown to black color. It had a specific gravity of 6.66.

The sulphides, galena, stibnite and pyrite, also the sulphate and carbonate of lead were reported by the earlier writers but none of these have been reported in recent years.

Tourmaline is quite frequent in its occurrence. It is present usually as radiating masses of columnar crystals included in quartz or in the gneiss along the contact. The masses are made up of columnar three sided, prismatic crystals of a jet black color that vary in size from six inches in diameter and several feet long, to those that have a hair-like form and size. No gem variety has been reported.

Beryl, of a bluish green to dingy yellow color, has been reported as occurring in crystals three to four feet long and eighteen inches in diameter. Specimens though not as good as these, are still obtainable.

Ilmenite has never been reported from these mines, though a specimen was presented to the late Dr. T. L. Watson, which was said to have been obtained here.

Zircon was reported from these mines by Watson[12] but no analyses were made.

Calcite occurs as a filling in the interstices of the crystalline masses of the blades of pea green cleavelandite. It is of an amber color and has assumed the shape of the cavity it fills showing that it is later than the albite. Some of the largest crystals are a centimeter long and a half centimeter wide.

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[9] Haines, R., Analysis of Helvite from Amelia County, Va., *Amer. Jour. Sci.*, Vol. 24, p. 155 (1882).

[10] Sloan, B. E., *Chem. News*, vol. 46, p. 493 (1882).

[11] Lee, O. I. and Wherry, E. T., *Amer. Mineral.*, vol. 4, No. 7, pp. 80–83 (1919).

[12] Watson, T. L., Zircon Bearing Pegmatites in Virginia, *Amer. Inst. Min. Eng.*, Vol. 55, pp. 936–947 (1917).

Cassiterite, hatchettolite, cyrtolite and leverrierite were reported by S. G. Gordon.[13]

Graphite was found by the writer in some of the smaller dikes nearby, as well as in the biotite gneiss, but none was found in these particular dikes.

ORIGIN

The unusual texture and composition of the dikes at the Rutherford Mines can be explained best, it seems, as resulting from a replacement process as set forth by W. T. Schaller.[14] In this paper he writes as follows, "Pegmatites containing rare minerals are made up chiefly of albite which has replaced more or less completely the original feldspar." The pegmatites in the area nearby are of the usual pegmatitic texture. The feldspar is chiefly orthoclase and microcline, the latter predominating. It seems quite likely that the dikes at the Rutherford Mines were originally of a composition similar to those of the other dikes in the area. Later they were replaced by the soda feldspar. This replacement was accompanied by, or followed, by the introduction of such minerals as microlite, manganotantalite, etc. These rare minerals are always found in the interstices of the reticulated albite or partially embedded in the feldspar itself. Such minerals as calcite and leverrierite were formed still later.

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[13] Gordon, S. G., Famous Mineral Localities, Amelia Court House, Virginia, *Am. Mineral.*, Vol. **3**, pp. 27–29 (1918).

[14] Schaller, W. T., Mineral Replacement in Pegmatites, *Am. Mineral.*, vol. **12**, pp. 59–63 (1927).

NOTES AND NEWS

THE FORMULA OF GLAUCONITE

A. F. Hallimond, *Geological Survey and Museum, London.*

In a recent discussion on the formula of glauconite (*Jour. of Geology*, 1927, vol. **35**, pp. 289–310) H. Schneider concludes that five new analyses published by him, together with five selected earlier analyses, are best represented by the formula $(K,Na)(Fe,Mg)(Fe,Al)_3Si_6O_{18} \cdot 3H_2O$, and not by the formula proposed by me in 1922 (*Mineral. Mag.*, 1922, vol. **19**, pp. 330–333), namely, $R_2O \cdot 4(RO,R_2O_3) \cdot 10SiO_2 \cdot nH_2O$. No numerical comparison of the two formulae is given, but it is not difficult to convert the molecular ratios given by Schneider into a comparable form by recalculating on the basis $SiO_2 = 1000$ as was done in my own paper.

The result is as follows:

	SiO_2	R_2O_3	RO	R_2O	$RO+R_2O_3$
5 new analyses (Schneider)					
1	1000	258	165	99	423
2	—	264	167	109	431
3	—	250	174	104	424
5	—	258	158	94	416
6	—	297	142	99	439
5 selected analyses (Schneider)					
11	1000	259	142	105	401
12	—	243	156	111	399
13	—	223	170	105	393
14	—	215	176	105	391
15	—	265	134	97	398
Theoretical values required by formulae of					
Hallimond	1000	—	—	100	400
Schneider	1000	250	167	83	417

Schneider's proposed value 83 for the alkalis seems inadmissible, for it will not explain any of the analyses; as regards the RO and R_2O_3 groups, Schneider's new analyses give indications of the replacement RO/R_2O_3 which I noted and which was confirmed independently by Ross (*U. S. Nat. Mus. Proc.*, 1926, vol. **69**, Art. 2), but the totals are a little higher than the value 400 found by other analysts. This is probably due (a) to the presence of a small amount of staining by free Fe_2O_3; Schneider says "Many of the pellets in No. 6 when examined under the microscope show pin points of limonite and limonite stain"; (b) to the presence of P_2O_5, for we read in a footnote to the analyses " . . . . any P_2O_5 that may be present is given in the analyses as Al_2O_3." As regards P_2O_5, Mr. Radley has been good enough to test the material he analyzed (No. 15 above) and finds only a trace of P_2O_5, limonite is absent and magnetite entirely negligible. His total for R_2O_3 is, therefore, the true value for that group only.

Reference is made to the similarity between X-ray powder photographs of glauconite and zinnwaldite. I believe these are frequently dominated by the oxygen pattern, which W. L. Bragg has shown to be common to many silicates, even when the chemical units vary in size, e.g., in the chondrodite group. Without a complete solution of the structure it seems doubtful whether similarity in X-ray pattern possesses any value as evidence of equality either in the molecular volume or in the number of oxygen atoms in the molecule. I would suggest that glauconite is derived from mica by the addition of an acid clay molecule, thus $K_2O \cdot 3Al_2O_3 \cdot 6SiO_2$ aq $+ Al_2O_3 \cdot 4SiO_2$ aq. $= K_2O \cdot 4Al_2O_3 \cdot 10SiO_2$ aq. (the formulae can be halved). This will account for the replacement R_2O_3/RO, the peculiar hydration and the structural similarity, without departing from the empirical formula required by the chemical composition.

The library of the late Thomas Leonard Watson has been secured by the Agricultural and Mechanical College of Texas for its department of Geology. The library consisting of approximately 1500 bound volumes and hundreds of separate papers and pamphlets will be known as the Watson Memorial Library and will form the nucleus of a much larger library in geology which the college authorities hope to build up. The library reflects Dr. Watson's interest in mineralogy, petrology and economic geology but there are also many works of a general nature including complete sets of the American Geologist, Journal of Geology, Economic Geology and the Bulletin of the Geological Society of America.

At the 100th regular meeting of the Newark Mineralogical Society, held on Oct. 7, 1928, two papers were presented, one by Dr. Alfred C. Hawkins on "New Jersey Minerals" and the second by Col. George C. Lewis on "Strategic Minerals and Metals."

The ninth annual meeting of The Mineralogical Society of America will be held at the American Museum of Natural History, New York City, December 27–29, 1928, in conjunction with the Geological Society of America and the American Association for the Advancement of Science. The first session of the Mineralogical Society will be held at the Museum at 2 P.M. Thursday, December 27. A preliminary list of titles of papers to be presented before the Society at this time will be found on the last two pages of this issue. The headquarters of the Society will be at the Hotel Astor, Times Square at 44th Street, where the banquet will be held on Friday, December 28. It is earnestly requested that everyone secure a *certificate* when purchasing a ticket to New York City to attend the American Association or the Mineralogical Society in order that the required number may be secured to insure reduced rates for the return trip.

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences, October 4, 1928

A stated meeting of the society was held on the above date with the president, Mr. Clay, in the chair. Thirty-six members and eleven visitors were present.

The following officers were elected: President, Harry W. Trudell; Vice-president, Florian Cajori, Jr.; Treasurer, Wilfred Broadbelt; Secretary, Samuel G. Gordon; Councilor, Morrell Biernbaum.

Mr. Harold Arndt described a trip to Canada, taken in company with Messrs. Clay, Boyle, and Biernbaum. The Vavaseur mine, McConnell Mine, Wallingford Mine, Mica Queen Mine, and Martin's Mine, near Ottawa, were visited. Fine specimens of apatite, phlogopite, pyroxene and amphibole were exhibited. Supplementary remarks were made by other members of the party, and a reel of moving pictures taken on the trip was shown.

Mr. Squier described a visit to Webb City. Mr. Cajori spoke briefly of several western localities visited during the summer. Mr. Strock presented an account of a trip to Paterson, Bedford, Branchville, Roxbury, Portland, and Haddam. A fine large columbite crystal from Kinkle's quarry, Bedford, N. Y., was exhibited, together with unusual specimens of rose quartz, beryl, muscovite, spodumene, laumontite, prehnite, almandite, and lepidolite. SAMUEL G. GORDON, *Secretary*

NEW YORK MINERALOGICAL CLUB

Minutes of the October Meeting.

A regular monthly meeting of the New York Mineralogical Club was held on the evening of October 17, 1928, with the president, Dr. Herbert P. Whitlock, in the chair. Twenty-two members were present.

Mr. Herman Cohen of Brooklyn, Dr. I. W. Drummond of New York City, and Mr. Louis Reamer of Orange, N. J., were elected to membership.

A committee was appointed to formulate plans for an annual social gathering of the Club. Plans were also laid for an excursion to the quarries at Paterson, N. J., on Election Day, November 6.

The program of the evening consisted of accounts of the summer collecting experiences of various members.

Mr. Radu described a trip to Maine, and exhibited rose quartz from Paris Hill, pollucite from Newry, cookeite from Hebron, and pink apatite from Norway, in that state.

Mr. Broadwell showed specimens of larsenite, calcium-larsenite, friedelite, and berzeliite from Franklin, N. J.

Messrs. Manchester and Whitehouse displayed specimens from Bedford, N. Y., including black tourmaline, columbite crystals, albite, and other minerals. One splendid group of black tourmalines contained a terminated crystal about 40 cm. long. A large microcline crystal was also a feature of this exhibit.

Mr. Allen exhibited ilmenite from East Providence, R. I., and Mr. Grenzig discussed the minerals of the limestone near Scottsville, N. Y.

Mr. Cooper described a visit to Idar and Oberstein, Germany, and discussed the cutting and dyeing of agates in this famous district.

HORACE R. BLANK, *Secretary*

NEW MINERAL NAMES

Zirklerite

E. HARBORT: Über zirklerite. Ein neues durch Thermo-Dynamometamorphose gebildetes mineral aus einigen Salzstöcken der norddeutschen Tiefebene. (Zirklerite, a new mineral formed through thermo-dynamicmetamorphism from some salt stocks of the North German Coastal plain), *Kali*, **22**, 157–161 (1928).

NAME: In honor of Bergrat Dr. Ing. *Zirkler*, General Director of the Aschersleben Potash Works.

CHEMICAL PROPERTIES: An oxychloride of aluminum, iron, magnesium and calcium. $2Al_2O_3 \cdot H_2O + 9(Fe,Mg,Ca)Cl_2 \cdot 2H_2O$. Analysis (after deduction of insoluble material, anhydrite and halite) Al_2O_3 12.29, $CaCl_2$ 2.47, $MgCl_2$ 6.83, $FeCl_2$ 57.20, H_2O 21.23. Decomposed by water with separation of alumina and iron hydroxide. Soluble in acids.

CRYSTALLOGRAPHIC PROPERTIES: Hexagonal; cleavage, rhombohedral.

PHYSICAL AND OPTICAL PROPERTIES: Birefringence weak, n about 1.552. When fibrous has parallel extinction. Hardness about 3.5. Sp. Gr. about 2.6.

OCCURRENCE: Found in the Adolfsglück shaft at Hope, Hanover, and other localities and forms the chief constituent of a light gray massive to fine grained rock in breccia like layers in halite or potash salts and is a geo-thermodynamic metamorphosed "Salzton."

W. F. FOSHAG

Kolbeckite

F. EDELMANN: Kolbeckite, ein neues sächsisches mineral. (Kolbeckite, a new mineral from Saxony.) *Jahrb. Berg-u-Hüttenw. Sachsen*, **100**, 73–74 (1926). (A preliminary description.)

NAME: In honor of Dr. *Kolbeck*, of the Freiberger Bergakademie.

CHEMICAL PROPERTIES: Contains much beryllium also Al, Mg, P_2O_5 and SiO_2, traces of Cu, Fe and SO_3. Suggested to be a beryllium phosphate or silicophosphate. Difficultly soluble in acids.

CRYSTALLOGRAPHIC PROPERTIES: Probably monoclinic and twinned. Habit short prismatic. Forms: prism, base and a clinopinacoid. Cleavage clinopinacoidal.

PHYSICAL PROPERTIES: Color cyan-blue to blue gray. Luster glassy to pearly. Strongly pleochroic. $H = 3\frac{1}{2}$–4. Sp. Gr. 2.39. Fracture conchoidal, brittle.

OCCURRENCE: Found at the Sadisdorf Copper Mine at Niederpöbel near Schmiedeberg, Saxony, on drusy quartz and chlorite gangue.

W. F. F.

Gudmundite

K. JOHANSSON: Mineralogische Mitteilungen. 1. Gudmundit, ein neues Mineral innerhalb der Markasitgruppe. (Gudmundite, a new mineral of the Marcasite group.) *Zeit. Kryst.*, **68**, 87–91 (1928).

NAME: From the locality, *Gudmund*storp, 3 km. north of Sala, Sweden.

CHEMICAL PROPERTIES: Iron antimony sulphide, Fe Sb S. Analysis: Fe 26.76, Ni trace, Sb 57.31, S 15.47. Total 99.57.

CRYSTALLOGRAPHIC PROPERTIES: Orthorhombic. $a:b:c = 0.6729:1:1.1868$. Forms: $m(110)$, $t(013)$, $q(011)$, $c(001)$. $m:m$ 67°52½′, $t:t$ 43°10′. Habit prismatic, elongated parallel to *a*. Twinning on *m*(111), penetration and contact twins, common.

Physical Properties: Color silver white to steel gray. Luster metallic. H = about 6.

Occurrence: Found in a small lead-zinc occurrence at Gudmundstorp, 3 mi. north of Sala, Sweden, in calcite veins in skarn with galena, sphalerite, pyrite and boulangerite. Arsenopyrite is present in the skarn but not in the veins.

W. F. F.

Haematophanite

Ibid.: pp. 102–107.

Chemical Properties: An oxychloride of lead and iron. $Pb(Cl,OH)_2 \cdot 4PbO \cdot 2Fe_2O_3$. Analysis: PbO 73.26, FeO 0.22, MnO 0.29, CaO 0.26, MgO 0.06, K_2O 0.17, Na_2O 0.38, Fe_2O_3 22.01, $FeTiO_3$ 0.20, Cl_2 2.17, H_2O 0.73, Insol. 0.42. Total 100.17, Minus $O = Cl_2$ 0.49, total 99.68. Average of two analyses. Easily soluble in acids.

Crystallographic Properties: Tetragonal, $c = 1.95$ (from Laue photogram). Cleavage micaceous.

Physical Properties: Color dark reddish brown. Streak yellowish red. Luster somewhat semi-metallic. H = 2–3. Sp. Gr. 7.70. Very thin plates transparent with blood red color. Optically negative.

Occurrence: With plumboferrite, jacobsite, andradite, copper cerussite in calcite at Jacobsberg as isolated thin plates up to 5 mm. in diameter or aggregated into lamellar aggregates.

W. F. F.

Gosseletite

Jean Anten: Le Salmien Métamorphique du Sud du Massif de Stavelot. (The Salmian Metamorphics to the South of the Massif of Stavelot). *Mem. Acad. Roy. Belg. Cl. Sci.*, Ser. 2, Vol. 5, fasc. 3, 34 pp., p. 18–19 (1923).

Name: In honor of J. *Gosselet.*

Chemical Properties: A manganiferous silicate. Composition unknown. Insoluble in acids.

Crystallographic Properties: Orthorhombic (from its optical properties).

Optical Properties: Color green. Pleochroic; X = clear greenish yellow, Y = crude green, Z = warm olive green. *n* high, birefringence very strong. Biaxial, positive, 2V large, 2E exceeds 120°. Plane of the optic axes bisects the obtuse angle of the prism. Cleavage parallel to *m*.

Occurrence: Found in quartzphyllade—a rock made up of specular hematite, phyllite and quartz with accessory rutile and spessartite—as knots intimately mixed with hematite. Locality Stavelot, southeastern Belgium.

W. F. F.

Lohestite

Ibid. p. 29.

A nearly amorphous substance occurring in knots in the metamorphic rocks of the Stavelot district represents a stage in the formation of andalusite. Named for M. *Lohest.*

W. F. F.

CORRECTIONS TO VOLUME 13

No. 2, p. 67, line 12 from bottom, for "unraninite" read uraninite.
No. 3, p. 79, line 4 from bottom, for "temprratures" read temperatures.
p. 85, line 12 from bottom, for "circunstances" read circumstances.
p. 96, 10th line, for "morphotrophy" read morphotropy.
p. 97, legend of cut, for 163 read 1863.
p. 114, 22nd line, for "agillite" read argillite.
No. 4, p. 155, 11th line, for "subvitrous" read subvitreous.
p. 159, 16th line from bottom, for "scharizerite" read scharizerit (the latter is the German form of mineral name).
p. 160, 3rd line from bottom, for "Canyon" read County.
No. 5, p. 201, 22nd line, for "acqua" read aqua.
26th line, for "sheer" read shear.
No. 6, p. 225, heading and accompanying text: The name rogersite is already in use (Dana, p. 746) so a new name will have to be assigned to the present mineral. Dr. G. M. Butler has suggested the name lausenite, after Carl Lausen the discoverer of the new mineral.
p. 227, second heading: the mineral "jeromite" is quite similar to that named arsensulfurite (Dana, Appendix 2, p. 101).
p. 240, 8th line, for "tholtiite" read tholeiite.
No. 7, p. 249, 3rd line, for "magnetic" read magnetite.
p. 272, 9th line, for "brakish" read brackish.
p. 273, 22nd line, for "lead" read led.
p. 275, 18th line, for "io" read of.
19th line, for "atmosphercf" read atmospheric.
p. 289, 7th line from bottom, for "Federow" read Fedorov. Same, next 2 pp.
p. 298, 7th line from top, for "$(\bar{5}24)$" read $(\bar{2}45)$.
p. 299, 18th line from top the same correction.
p. 343, Table IIa, Col. 4, last line for "3.339" read 3.368.
p. 345, 3rd line from top for "by" read of.
p. 361, 4th line from bottom, for "southease" read southeastern.
p. 409, 1st line, for "maty" read many.
No. 8, p. 427, 1st line in Shepherd's quotation, for "Mervin" read Merwin.
p. 443, 12th line, for "dentritic" read dendritic.
No. 9, p. 457, legend for Fig. 1, North face of Wodgina greenstone massive and adjacent granitic coastal plain.
p. 458, legend for Fig. 2, Northermost workings on main tantalic vein, Wodgina. Pilbarite and other uranium-thorium minerals were discovered here; also much lithiophilite, a boulder of which is indicated by the hammer in the center of the picture.
p. 492, 8th line, for "SO_2" read SO_3.
p. 493, 10th line from bottom, for "vezelyite" read veszelyite.
No. 10, p. 498, 21st line from bottom, for "Farnum" read Farnham.
p. 500, last sentence, after "equilibrium" insert "is nearly vertical."
p. 514, No. 4 in table, should read "Phenylisothiocyanate."

Note to article on zircon, page 390: Since this was written Dr. Hevesy has very kindly determined the hafnium oxide in the zirconia precipitate from this zircon. He reports the presence of 1% of HfO_2.

INDEX TO VOLUME 13

Prepared by L. S. Ramsdell

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